Minimizing Methane Emissions – Strategic Project Evaluation and Implementation

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Methane Emission Reduction Technologies and Practices

- Some best practices for reducing emissions include:
  - Replace high bleed pneumatics with low bleed or instrument air
  - Directed Inspection & Maintenance (DI&M)
  - Replace centrifugal compressor wet seals with dry seals
  - Economic rod packing replacement in reciprocating compressors
  - Install flash tank separators and electric pumps in dehydrators
  - Install vapor recovery units on tanks and casinghead

Pneumatic Controller Mitigation Options

- Retrofit pneumatic high-bleed gas controllers with low-/no-bleed controllers to reduce gas emitted
- Replace pneumatic pumps with electric pumps, including solar electric pumps for smaller applications such as chemical and methanol injection
- Install instrument air system for pneumatic gas supply/use

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Pneumatic Controller Mitigation Options

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Economics of Pneumatic Controller Mitigation Options

Options	Capital Costs	Annual O&M Costs	Emission Savings	Payback Period
Replace or Retrofit with low-/no-bleed controllers	$400 - $3,500	Negligible	$150 - $1,820*	2 months to 3 years
Replace with electric pumps (including solar electric pumps)	$2,000	$100-$1,000	$600**	3-4 years
Install instrument air system	$45,000 - $75,000	$13,100***		

*Emission savings number is calculated assuming 8,760 hours of operation and varies depending on the current natural gas price.
**Emissions savings are typically 200 Mcf/pump and at $3/Mcf
***This assumes that electricity is $0.75/kW-hr and that the main compressor runs at full capacity half of the time

Fugitives Mitigation Options

- Direct Inspection and Maintenance (DI&M)
- Periodic, directed surveys and measurement
- Prioritize significant leaks that are cost-effective to repair or pose a safety or environmental concern
- Repair on the spot where possible
- Plan larger repairs for next shut down
- Minimizes the potential for big leaks, provides early detection when they occur
- Future surveys directed by findings will be more efficient and economical

Source: Heath Consultants

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Economics of Fugitives and Leaks Mitigation Options

Options	Capital Costs	Annual O&M Costs	Emission Savings
DI&M conducted by an internal team with purchased DI&M equipment	$100,000[1]	$1,200 - $2,400[2]	100 - 200 ft^3/hour (3 - 6 m^3/hour)
DI&M conducted by an internal team with rented DI&M equipment	-	$1,000 (IR camera) $400 (high volume sampler) $1,200-$2,300 (labor)	900 - 1,700 Mcf (25 - 50 thousand m^3)[3]
DI&M conducted by outside consultants	-	$14,000 - $55,000	900 - 1,700 Mcf (25 - 50 thousand m^3)[3]

1 - Based on an estimated cost of $85,000 for FLIR Model GF320 infrared camera6 and $15,000 for a high volume sampler.
2 – Based on surveying 14,000 components within two days by a two-man team in a small facility and 56,000 components within four days by a two-mean team in a large facility. Estimated labor rate - $30.46/hour. Equipment used: IR camera and a high volume sampler.
3 – Assuming 100 - 200 ft^3/hour (3 - 6 m^3/hour) of leak reductions.

Source: CCAC O&G Methane Partnership – DRAFT Technical Guidance Document Number 2: Fugitive Equipment and Process Leaks

Mitigation Options for Reciprocating and Centrifugal Compressors

- Replace packing when leak reduction expected pays back cost
- Route gas to useful outlets (a fuel gas system, a vapor recovery unit, a compressor inlet)
- Dry seals can be retrofitted to a wet seal compressor
- Degassing at intermediate – rather than atmospheric – pressure reduces emissions and allows pressurized gas to be directed to beneficial use
- A low cost alternative to replacing wet seat compressors is to retrofit a vapory recovery system to capture vented methane

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Economics of Converting Wet Seals to Dry Seals

- Compare costs and savings for a 6-inch shaft beam compressor
  - Retrofit dry seals versus replace existing wet seals

Cost Category	Dry Seal ($)	Wet Seal ($)
Implementation costs[1]		
Seal costs (2 dry @ $13,500/shaft-inch, with testing)	162,000	
Seal costs (2 wet @ $6,750/shaft-inch)		81,000
Other costs (engineering, equipment installation)	162,000	0
Total implementation costs	324,000	81,000
Annual operating and maintenance	14,000	140,000
Annual methane emissions (@ $3.00/Mcf; 8,000 hours/year)		
2 dry seals at a total of 6 scfm	8,640	
2 wet seals at a total of 100 scfm		144,000
Total costs over 5-year period	394,000	781,000
Total dry seal savings over 5 years		
Savings	387,000	
Methane Emissions Reductions (Mcf) (at 45,120 Mcf/yr)	225,600 Mcf/yr	

[1]**Source:** CCAC O&G Methane Partnership – DRAFT Technical Guidance Document Number 3: Centrifugal Compressors with “Wet” (Oil) Seals

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Economics of Wet Seal Degassing

Equipment	One Centrifugal Compressor, Capital Cost ($2011)	Centrifugal Compressor (4) Station, Capital Cost ($2011)
Seal Oil Disengagement Vessels (2 per compressor)	$19,000	$76,000
Seal Oil Gas Demister – Low Quality Gas	$9,000	$9,000
Seal Oil Gas Demister – High Quality Gas	$5,000	$5,000
Total	**$33,000**	**$90,000**
Annual Gas Savings	**$65,200**	**$260,800**

Note: Assumed two seals per centrifugal compressor and four centrifugal compressors at the station. An individual seal oil/gas disengagement vessel costs $9,500 per seal. Annual gas savings were calculated assuming 8,000 hours of operation per year and gas value of $3 per million Btu

Source: CCAC O&G Methane Partnership – DRAFT Technical Guidance Document Number 3: Centrifugal Compressors with "Wet" (Oil) Seals

Economics of Compressor Mitigation Options

- "Leak reduction expected" is the difference between current leak rate and leak rate with new rings

Rings Only

Rings:	$1,620
Rod:	$0
Gas:	$3/Mcf
Operating:	8,000 hours/year

Leak Reduction Expected cf/hour (m^3/hr)	Payback (months)
145 (4.1)	6
74 (2.1)	12
39 (1.1)	24
27 (0.8)	36

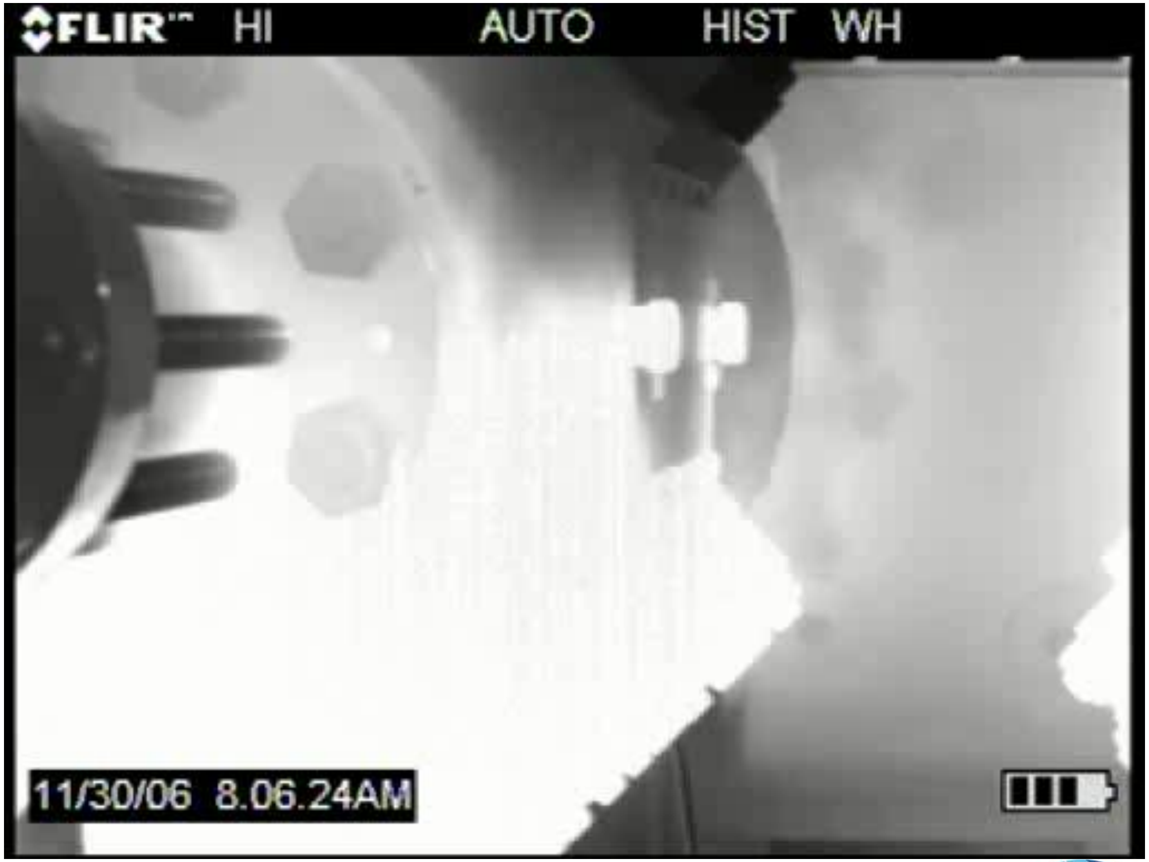
Rod and Rings

Rings:	$1,620
Rod:	$9,450
Gas:	$3/Mcf
Operating:	8,000 hours/year

Leak Reduction Expected cf/hour (m^3/hr)	Payback (months)
991 (28)	6
507 (14.4)	12
266 (6.4)	24
185 (5.2)	36

Based on 10% interest rate
Mcf = thousand cubic feet

Economics of Compressor Mitigation Options



Video Courtesy
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Glycol Dehydrator Mitigation Option

- Dehydrator with a flash tank separator and gas assist-pump, route gas to beneficial use or flare
- Dehydrator with no flash tank separator and with gas assist pump, route reboiler vent to a vapor recovery unit, fuel gas or flare
- Electric glycol circulation pump

Glycol Dehydrator Unit
Source: GasTech

Economics of Glycol Dehydrator Mitigation Options

Options	Capital Costs	Installation Cost	Annual O&M Costs	Emission Savings	Payback Period
Flash Tank Separator	$3,375-$6,751	$1,684-$3,031	nil	3,600-10,700 Mcf per year	3-9 months
Vapor Recovery Unit	$2,000	-	$100-$1,000	790 Mcf per year	0-1 years
Electric Pump	$1,425-$12,953	$143-$1,295	$263	360-36,000 Mcf per year	2-29 months

Source: CCAC O&G Methane Partnership – DRAFT Technical Guidance Document Number 5: Glycol Dehydrators

Mitigation Options for Storage Tanks

- Route tank vapors to a Vapor Recovery Unit (VRU)
- Route tank vapors to a flare/combustion device
- Capture vapors from both oil and condensate tanks

Photo Courtesy HY-BON Engineering

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Mitigation Options for Storage Tanks

Video Courtesy HY-BON Engineering

Economics of Storage Tank Mitigation Options

Project Component	Implementation Cost	Annual Costs
VRU Capacity	25 – 500 Mcf/day	
VRU Cost	\$45,000 - \$750,000	
Installment Cost	\$33,750 – \$97,500	
Annual Operating Cost (electricity)		\$8,400 – \$21,000
Total Cost	\$87,150 - \$868,500	
Annual Gas Savings Condensate Sales	\$43,000 - \$864,000 \$60,000 – \$340,000	
Payback if gas is \$3/MMBtu	3 months – 10 months	

Source: CCAC O&G Methane Partnership – DRAFT Technical Guidance Document Number 9: Casinghead Gas Venting

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Vapor Recovery Case Study
Chevron Angola

Chevron's largest methane capture project in 2005/2006

Phase I captures approximately 25MMCFD of previously vented gas in Angola; offshore & onshore sources

Chevron's goal to maximize condensate production, and reinject remaining gas into underground storage for future use

Chevron selected HY-BON to design, manufacture & commission the VRU packages. The project utilized 3 electric drive, dual oil flooded rotary screw VRUs, each capable of capturing 8.4 MMCFD at atmospheric pressure and compressing to 120 psig

Source: Excerpts and data from Chevron presentation 2010 GGFR Conference, Amsterdam; Mr. Frank Christiano

Vapor Recovery Case Study Chevron Angola

- One of the more challenging aspects of this project was designing for the capture and first stage compression of gas streams:
  - From multiple sources and varying quality
  - That are NGLs rich; and
  - Very low pressure

- Vapor Recovery Technologies Considered
  - Dry Screw Compressors
  - Turbo Compressors (Ejectors)
  - Wet (Oil Flooded) Screw Compressors

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Vapor Recovery Case Study Chevron Angola

- The selected Vapor Recovery System had several unique design elements:
  - Chose electric motor drive, rotary screw compressors – best solution for high BTU, wet gas and the required 3 to 115 psig (0.21 to 7.93 barg) pressure differential.
  - Systems for handling condensate dropout and potential slugs of liquids from the field
  - Six compressor trains provide flexibility for a wide volume range, and redundancy to minimize downtime
  - System designed to operate as one integrated unit, which responds automatically to changes in volume

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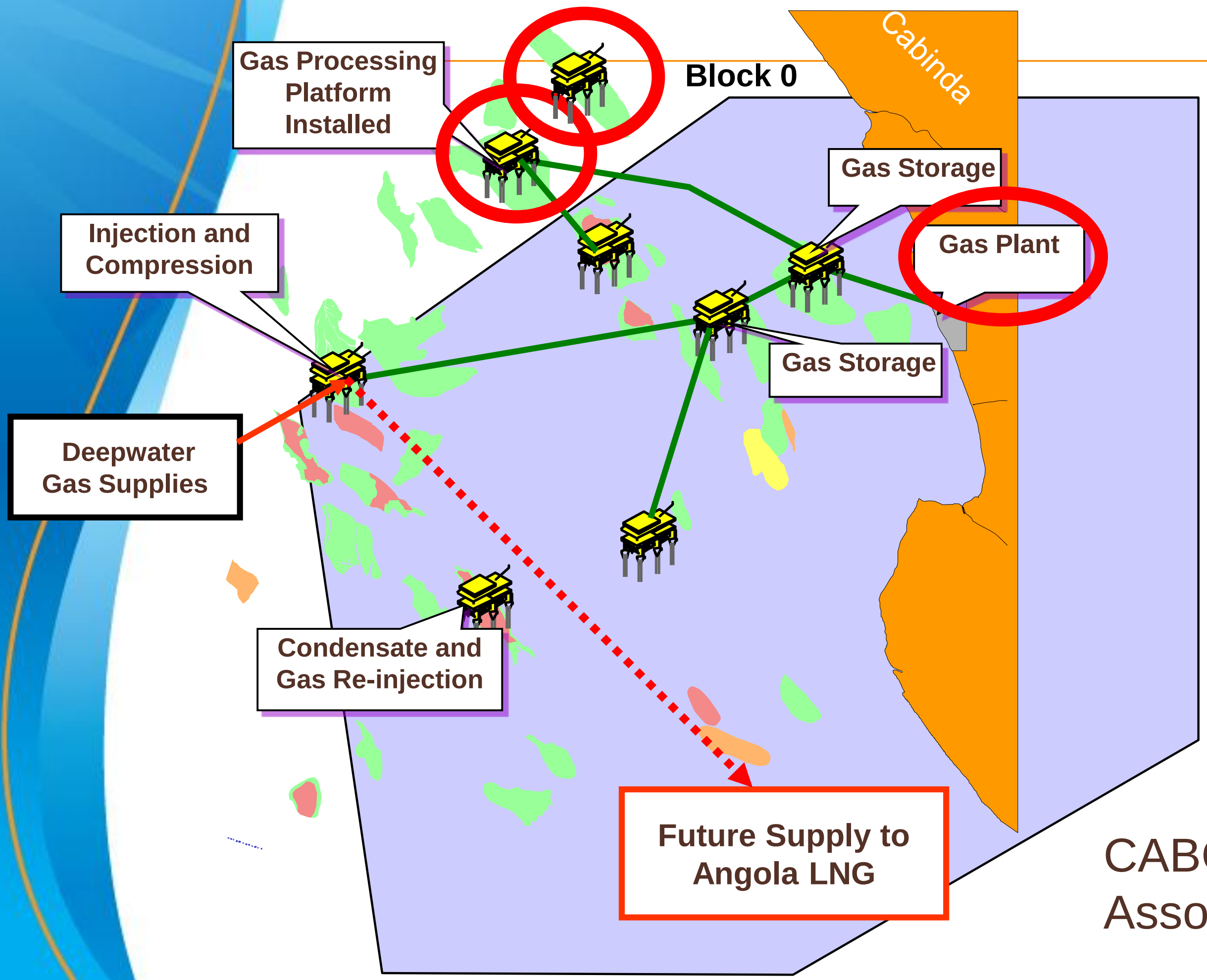
Vapor Recovery Case Study
Chevron Angola



- **Routine Flare Elimination**
- **Gas to Angola LNG**
- **Create Value**

CABGOC Operated Blocks
Associated Gas Infrastructure

Vapor Recovery System

One of 3 HY-BON Vapor Recovery Units that capture 25 MMscfd of associated gas for the Cabinda Gas Plant project

Photo Courtesy HY-BON Engineering

Vapor Recovery System Installation

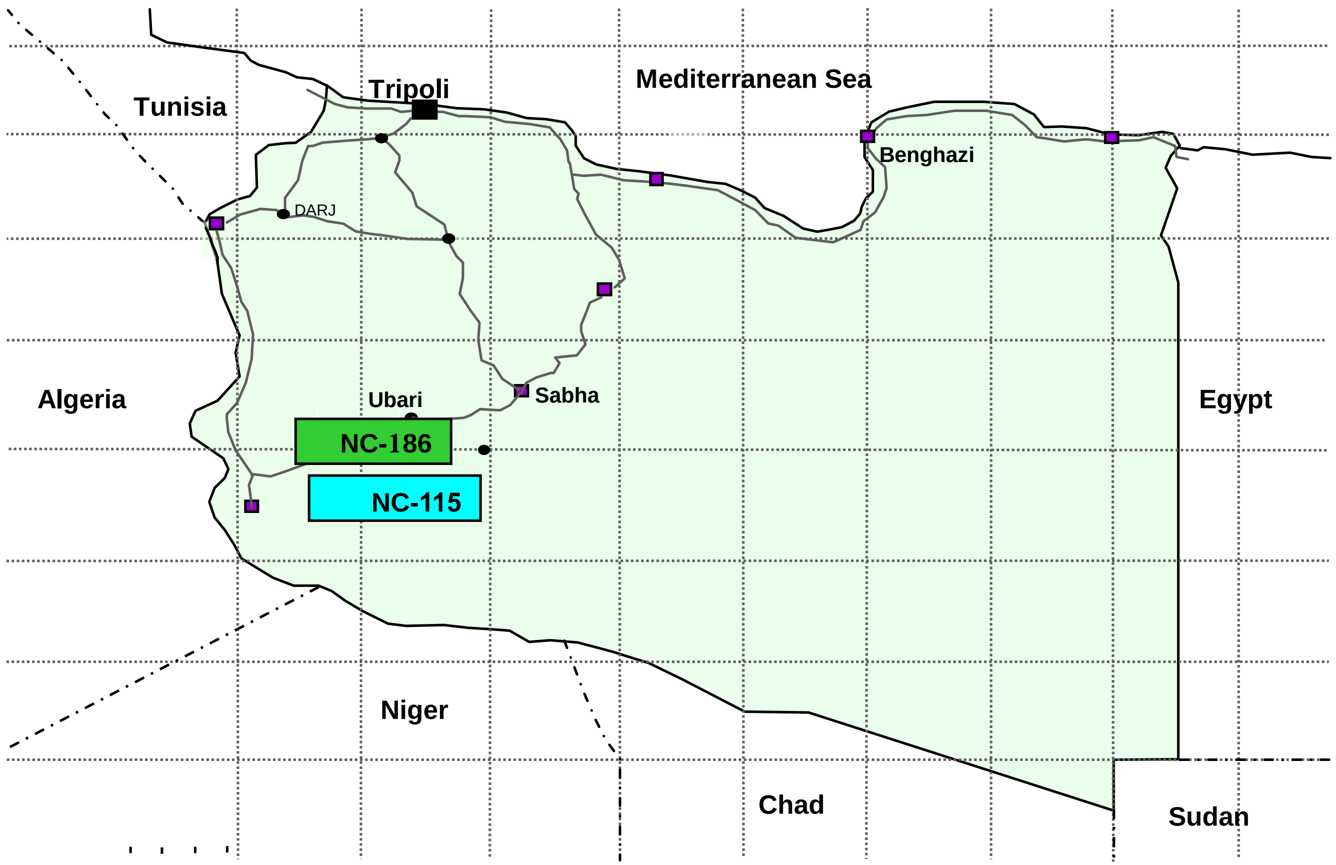
Photo Courtesy HY-BON Engineering

Vapor Recovery Case Study Chevron Angola; Results

- Elimination of multiple flared and vented gas sources
- Production of condensate exceeded project expectations
- **Project Environmental Impact - removal of 25 MMSCFD (708,000 m3/day) has the same greenhouse gas effect as:**
  - Removing 812,000 cars from the road for one year
  - Planting 1.1 million acres (4,450 square kilometers) of trees – an area larger than the state of Rhode Island or the country of Switzerland

  - Source: 2010 Chevron Presentation (Mr. Frank Christiano) at World Bank GGFR Conference, Amsterdam

Vapor Recovery Case Study
Akakus Libya (Repsol)



Vapor Recovery Case Study Akakus Libya (Repsol)

Main Activities:

- Exploration, drilling and oil production from two main concessions:
- NC-115 (8 fields and three main GOSP's) total production 230,000 bbl/day.
- NC-186 (6 fields and one GOSP) total production 130,000 bbl/day.

Production history:

- December 1996 the early production started with 50,000 bbl/day (EPF).
- December 1997 the main GOSP in NC-115 A was Commissioned.
- October 1998, the 2.7 MMbbls capacity storage terminal including the 720 KM transmission pipeline were put in operation.
- End of 1999 the first gas compression package was put in operation for feeding two power generation units with fuel gas
- The early production started @ NC186 in 2004 (EPF), the power demand had increased and accordingly the power units were increased to 4 units with two units operating on gas and other two units operating on treated crude oil.
- During 2005 all satellite fields were connected to the main GOSP A NC-186.

- Direct excerpt: Akakus presentation, Oil & Gas Technology Forum

Vapor Recovery Case Study Akakus Libya (Repsol)

GAS UTILISATION PROJECT STRATEGY

- In 2006 the AOO Gas Utilization feasibly study was finalized with a recommendation to implement the project in to two phase:

- **Phase I**:
  - In this phase the VRU packages were introduced to treat the low pressure tank gas. This was the first installation in Libya, which was focused on flare reduction of Tank vapor/ gas by recovering the condensate and diverting the remaining gas to the main plant compression system. The Project was completed in late 2008 .
  - By installing the VRU and splitting the existing compression systems in to two independent trains the fuel gas had increased to allow four power generation units to operate on Gas and maximizing the condensate recovery thereby reduce flaring.
  - Awarded Vapor Recovery Units design and Fabrication to Hy-Bon Engineering, a company with 55 years experience in this field.

Direct excerpt: Akakus presentation, Oil & Gas Technology Forum

Vapor Recovery Case Study Akakus Libya (Repsol)

Picture of the flares at NC-115 location before the VRU's were installed

Photo Courtesy HY-BON Engineering

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Tank Gas Composition

	NC-186 % mole	NC-115 % mole
Nitrogen	0.04	0.04
CO_2	0.66	0.90
C1 Methane	1.16	0.97
C2 Ethane	6.33	5.10
C3 Propane	2.94	19.22
C4 Butanes	5.84	32.50
C5 Pentanes	14.45	20.00
C6 Hexane	5.31	5.40
C7 Heptanes	3.50	2.82
C7+	3.98	6.15
H_2O	16.38	6.90

- Direct excerpt: Akakus presentation, Oil & Gas Technology Forum

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“Lessons Learned” on Akakus Libya (Repsol) VRU Project

- Volume of condensate is dependent upon volume of gas and gas composition.
- As the gas is cooled after compression (typically to 7° C above ambient temperature) the hydrocarbon liquids condense. This condensate can be captured in a vessel and delivered via pipeline or truck for further processing.
- One beneficial use is to “spike” (blend) the condensate into the crude oil stream. This serves to lighten the crude oil and increase the API gravity of the crude. This would involve pumping the condensate to the pressure of the crude oil pipeline. The condensate will blend with the crude oil, and depending upon the length of the line, virtually all flashing will be eliminated as the condensate is absorbed into the crude oil.
- This condensate can also be taken away via tanker truck. In this scenario, the condensate is taken from the compressor discharge scrubber via pump or pressure flow to an atmospheric pressure vessel. Any gas that flashes in this vessel can be taken back to the suction of the compressor. The recovered liquids will stabilize and can be put into a truck.
- In some cases, the installation may be close enough to a Natural Gas Liquids plant to pump the condensate from the discharge scrubber, via pipeline, for further refinement of the liquids.

- Direct excerpt: Akakus presentation, Oil & Gas Technology Forum

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Vapor Recovery Case Study Akakus Libya; Results

Location	Processed Tank Gas MMSCFD	VRU Recovered Condensate	Additional recovered condensate
NC-115	4	1200 blls/day@ 60 psig	1750 blls /day @ 150 psig
NC-186	2	275 blls/day@ 60 psig	1121 blls/day @ 250 psig

Location	No of VRUs	Pay back time	Co2 emission reduction
NC-115	3	3 months	866 tons/day
NC-186	2	8 months	406 tons/day

- Direct excerpt: Akakus presentation, Oil & Gas Technology Forum

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Vapor Recovery Case Study Akakus Libya; Results

Picture of the flares at NC-115 after the VRU's were installed. Units capturing 4 MMscfd (Four million standard cubic feet per day) of previously flared or vented natural gas streams.

Photo Courtesy HY-BON Engineering

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Casinghead Gas Mitigation Options

- Route casinghead gas to tanks with new or existing VRU systems
- Route to a flare

Photos Courtesy HY-BON Engineering

Casinghead Gas Mitigation Options

Mitigation Option for Casinghead Gas: Install VRU or Wellhead Compression

- Vapor recovery units or wellhead compression can capture up to 95% of hydrocarbon vapors from Casing venting
- Recommend electric motor drive packages if power is available
- If natural gas engines are used to drive compressors, be sure to use clean, dry fuel gas for engines
- Multiple wellheads can often be piped to a centralized compressor or VRU to reduce costs (up to 30 wells)
- Reducing casinghead backpressure often increases production in older, mature wells. Ask if the gas is being vented… it usually is. If so, this gas is typically cost effective to capture.

Mitigation Option for Casinghead gas: Flaring

- Casinghead vent emissions can also be routed to a new or existing flare
  - There are no economics to route to a flare as there are no gas savings
- Casinghead gas can also be routed to tanks with new or existing VRU systems
  - Cost savings derive from increased oil production and the capture and sale of previously vented gas

Economics of Vapor Recovery: Casinghead Gas

- The major costs include:
  - Equipment costs of compressor package/VRU system, piping, liquid treatment equipment, pressure regulators
  - Installation costs
  - Annual operating and maintenance (O&M) costs for electricity or fuel
- Compressor Package
  - This example is based on a 30-HP electric rotary compressor (able to deliver up to 200 Mcf of gas per day to a 100-psig sales line)

Project Component	Implementation Costs	Annual Costs
Capital Cost	$12,500	--
Installation Costs	$18,750	--
O&M Costs (Electricity)	--	$7,350
Gas Savings	--	-$219,000
Total	$31,250	-$211,650

Source: CCAC O&G Methane Partnership – DRAFT Technical Guidance Document Number 9: Casinghead Gas Venting

Well Venting during Completions Mitigation Options

- Implement reduced emission (green) completions, using special flow-back equipment if necessary
- Connect gas separator or tank vent to portable flare

Source: Weatherford

Portable REC Equipment

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Economics of Well Venting Mitigation Options

- Partner company in Ellis County, Oklahoma
  - RECs on 10 wells using energized fracturing
  - Total cost of $325,000
  - Estimated net profits: $340,000, or $34,000 per well on average
- Partner company in Green River Basin, Rocky Mountain region
  - RECs on 106 total wells, high and low pressure
  - Capital investment of ~$500,000 per skid (including portable three-phase separators, sand traps, and tanks)
  - Conservative net value of gas saved: $20,000 per well
- Partner company in Fort Worth Basin, Texas
  - RECs on 30 wells
  - Incremental cost of $8,700 per well
  - Conservative net value of gas saved: about $50,000 per well

* Natural Gas STAR Lessons Learned document: http://www.epa.gov/gasstar/documents/reduced_emissions_completions.pdf

Liquids Unloading Mitigation Options

- Foaming agents (“soaping”)
- Velocity tubing (increase gas velocity to lift liquids)
- Install a plunger lift
- Install a liquids pump
  - Beam pump (sucker-rod pump, pump jack)
  - Electric submergence pump (ESP)
  - A pump is the ultimate solution which can be postponed by the above techniques

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Economics of Liquids Unloading Mitigation Options

Options	Capital Costs	Annual O&M Costs	Emission Savings	Increased Production
Conventional plunger lifts	$1,900 - $7,800	$1,300	24 Mscf/yr (680 m^3/yr) for 1 hr/blowdown	91 Mcf/day (2.6 Mm^3/day) after 30 days
Automated "smart" plunger lifts	$5,700 - $18,000	-	524 Mscf/well/yr (15 Mm^3/well/yr)	5,000 Mcf/well/yr (140 Mm^3/well/yr)
Downhole pumps	$25,900 - $51,800	$1,300 - $19,500 (maintenance) $13,200 (well treatment) $1,000 - $7,300 (electricity cost)	770 - 1,600 Mcf/well/yr (22 – 45 Mm^3/well/yr)	n/a
Foaming agents	$500 - $9,900	$6,000 (surfactants)	180 - 7,400 Mcf/well/yr (5 – 210 Mm^3/well/yr)	360 - 1,100 Mcf/well/yr (10 – 31 Mm^3/well/yr)
Velocity tubing	$7,000 - $64,000/well		150 - 7,400 Mcf/well/year (4 – 210 Mm^3/well/yr)	9,125 - 18,250 Mcf/well/yr (260 – 520 Mm^3/well/yr)

Source: CCAC O&G Methane Partnership – DRAFT Technical Guidance Document Number 7: Well venting for liquids unloading.

Contact and Further Information

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